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ABSTRACT

A study demonstrated how recordings of ongoing electroencephalographic (EEG) activity can be used to study global aspects of complex cognitive processes that take place during the reading and encoding of connected discourse. The methods utilized allowed the study of complex cognitive processes within an ecologically valid paradigm (natural reading) and demonstrated that EEG activity in the alpha bandwidth is a reliable correlate of modal processing style, not just a measure of mental alertness. Right handed male and female college students read two poetry selections and were told that they would be expected to recall as much of the poem as possible (in any order they wished) immediately after reading the last stanza. Electrophysiological recordings were made during the reading of each stanza from two parietal temporal sites that allowed for observations of differential hemisphere activation. Results support the notion that various "cognitive styles" differentially affect the encoding and recall of diverse prose material (expository text and poetry). A metacontrol system, entailing subcortical brain structures, and differential brain organization were implicated in observed cognitive style differences. The results suggest that curricula should be developed to meet the needs of at least the major types of cognitive styles which have been, and will be, identified by researchers in the next several years. Since the brain's metacontrol system is most adaptive when it has numerous strategies at its disposal, such as analytic and holistic strategies, teaching strategic knowledge and cognitive flexibility should be stressed to all students. (SRT)

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Electrophysiological Determinants of Cognitive Style: Implications for Educational and Psychological Research

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Running head: COGNITIVE STYLE

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Abstract

The goal of this paper is to demonstrate how recordings of ongoing electroencephalographic (EEG) activity can be used to study global aspects of complex cognitive processes that take place during the reading and encoding of connected discourse. Results of several studies (using cortically recorded EEG in the alpha bandwidth as a dependent measure) support the notion that various "cognitive styles" differentially affect the encoding and recall of diverse prose material (expository text and poetry). A metacontrol system, entailing subcortical brain structures, and differential brain organization are implicated in observed cognitive style differences. Educational implications of modal processing differences are discussed.

Electrophysiological Determinants of Cognitive Style:

Implications for Educational and Psychological Research

In general the goal of this presentation will be to demonstrate how recordings of ongoing, scalp recorded, electroencephalographic (EEG) activity can be used to study global aspects of complex cognitive processes that take place during the reading and encoding of connected discourse. In the process of developing this point it will become apparent that the use of such a metric has an impact on the study of cognition and memory for two reasons. First, the methods we utilize allow the study of complex cognitive processes within an ecologically valid paradigm (natural reading). Second, we will demonstrate that EEG activity in the alpha bandwidth (8-13 Hz) is a reliable correlate of modal processing style, not just a measure of mental alertness as proposed by Andersen & Andersson (1968). Demonstration of these points provides an important platform for theoretical and empirical investigations of individual differences in cognitive processing, thus substantiating the claim that electrophysiological measures have important educational implications.

One could argue that <u>any metric that helps shed light on cognition will have</u> implications for education. Without a doubt such an argument could be made in regard to the contributions of electrophysiological measures of <u>isolated</u> aspects of cognition. Unfortunately, educators and students exist in the reality of complex, interactive, language processes and the impact that written or spoken language has on knowledge acquisition, and knowledge representation, as well as creative thinking and problem solving.

For the most part average evoked potential (AEP) studies have not addressed themselves to such dynamic aspects of cognition and memory. The

primary reason for this (which, by the way, does not constitute an oversite) is a limiting methodological constraint. In the typical EP (Evoked Potential) study epochs (time slices of ongoing EEG activity) must be time locked to an evoking stimulus (e.g., flash of light or a single word or word pair) in order to derive relatively noise free electrical averages that represent the brains unique perceptual or cognitive response to the stimulus. Such methodological constraints are likely to encourage attentional biases and artificial processing strategies that you wouldn't find were stimulus material presented in a more ecologically valid manner. Not all EP studies would fall prey to such arguments, in fact a promising exception appears to be the probe-technique developed by the Shucards' and their colleagues (Shucard, Shucard, Cummins, & Campos, 1981; Shucard, Shucard, & Thomas, 1977), however, its value in studying complex cognitive processes is just beginning to be explored.

The methodology and dependent measures used by Bruce Dunn and his colleagues (Dunn, 1985a, 1985b; Dunn. Gould, & Singer, 1981; Reddix, 1983; Reddix & Dunn, 1984) is a partial reaction to, but not a criticism of, reductionistic methodologies that attempt to study isolated aspects of cognition. We chose to free ourselves from the simplifying assumptions and limited generalizability that go along with such research by studying encoding processes that take place during reading of connected discourse. This necessarily raises the level of abstraction and difficulty in interpreting our results. However, we argue that such a level of abstraction may be a necessary precursor to attempts to bridge the gap between knowledge of the brain (which neuroscience and neuropsychology are accumulating at at rapid rate) and an understanding of mind (how functional neural substrates interact

during complex mental activity). It seems inevitable to us that such knowledge will guide studies of isolated mental processes as well as guide theorizing about the functional organization of the brain and its impact on cognition.

Using a natural reading task implies that we are not studying static or isolated mental processes. That is, we are studying complex rather than simple phenomenon. It fact "reading can be shown to involve every conceivable activity of the mind [and it must be realized that] every psychological component of reading, every aspect of a theory of reading, any way you can divide up the reading pie is a possible source of differences among individuals...." (Spiro & Myers, 1984, p. 471).

It is obvious then that we have traded the study of isolated cognitive processes and the lack of generalizability that go along with them for a potential increase in the variance of our dependent measures. However, as will be seen, there is ample experimental and theoretical evidence pointing to the possibility of accounting for a significant portion of this variance by postulating individual differences in modes of information processing and encoding between and within individuals. Specifically, our experimental approach allows for the exploration of the notions that: a) modal processing style can account for significant individual differences in the encoding and recall of expository text and poetry, b) relative modal processing style can be identified and monitored using scalp recorded electroencephalographic activity (EEG), and c) hemispheric dominance for language processing may be an overly simplistic way to think about the dynamic aspects of text processing, encoding, and individual differences, while masking the whole brains complex

involvement in language processing.

Bimodal Theory

Our theoretical basis for postulating modal processing styles is somewhat eclectic, and will require a brief review of relevant research in order to establish modal style (general processing strategy) as a fundamental aspect of cognition worthy of empirical investigation. Theoretical perspectives related to the functional organization of the hemispheres (and that organizations impact on information processing) will be briefly reviewed. This will be followed by a discussion of bimodal theory and its implications for empirical investigations of "cognitive style."

Older theories of brain functioning proposed that each cerebral hemisphere is specialized for a different cognitive or processing style (e.g., Galin, 1974; Levy-Agresti & Sperry, 1968). It was argued that the left-hemisphere operates in an analytical, logical mode for which words are an excellent tool, and that it processes information in a linear, serial, or sequential manner. In contrast, the right hemisphere seems to operate in a holistic, gestalt mode, which is particularly suitable for spatial relations, as well as music. Furthermore, it has been postulated that the right hemisphere processes information in a more simultaneous or parallel manner. Summarizing, then, many researchers believe that the left hemisphere works more with "parts" and the right hemisphere with "wholes."

To further complicate matters, current research indicates that both hemispheres have some analytical and holistic processing capability (Cohen, 1975; White & White, 1975; Sergent, 1982a, 1982b; Sergent & Bindra, 1981). In fact, there is a modest, yet growing body of research which indicates that the

right hemisphere has a fairly well-developed language capability (e.g., Heeschen & Jurgens, 1977; Zaidel, 1976, 1977; also see Searleman, 1977 for an extensive review). These results and those of others (e.g., Basso, Bisiach, & Capitoni, 1977; Freides, 1977; Hardyck, Tzeng, & Wang, 1978; Heeschen & Jurgens, 1977; Levy & Trevarthen, 1976) suggest that analytic and holistic processing modes could best be viewed as unique products caused by different mixtures or interactions of the hemispheres, rather than be seen as separate and exclusive functions of each (Dunn, 1985a). Several recent models have been postulated to account for the apparent interactive nature of the hemispheres (Das, Kirby, & Jarman, 1975; Goldberg & Costa, 1981; Levy & Trevarthen, 1976; Luria, 1973). All of which have a "whole brain" or "interactive hemispheric" flavor to them.

In line with such an integrative perspective Levy and Trevarthen (1976), Dunn (1983, 1985b), Kraft (1985), and Zutell (1985) conclude that information processing may be organized by a metacontrol system which is located in mid and lower brain areas (e.g., thalamus, limbic system, etc.). This system has the primary responsibility for regulating hemispheric processing. Furthermore, the metacontrol system makes its decision prior to actual information processing, and the chosen hemisphere remains in control even if, as a consequence of that decision, performance declines. In addition. Levy and Trevarathen (1976) stress the possibility that perception is both an active constructive process and that it is highly dependent upon the internal state of the subject, which in turn depends on constraints imposed by learned values, expectations, knowledge, and intentions.

Such a view reconciles itself nicely with 'laterality' research findings

showing that strategy effects may be responsible for the reversal of lateral asymmetry effects when using the same stimuli with different instructions (see Bryden, 1982 for a review). Visual half-field studies (e.g., Cohen, 1972; Geffen, Bradshaw, & Nettleton, 1972; Segalowitz & Stewart, 1979) as well as dichotic listening research findings (e.g., Spellacy & Blumstein, 1970) have demonstrated that processing strategy may be responsible for reversing hemisphere laterality effects. For example, in the visual domain it was found that letter pairs yield a right visual-field effect (left hemisphere) when subjects were asked to decide if they had the same name. However, the visual field effect was severely attenuated or reversed when the task required a decision as to whether or not the letter pairs constituted a physical match. It is important to underscore the notion that the manner or strategy of processing, in contrast to particular characteristics of the stimuli or task, can be implicated in observed asymmetry effects in these and other laterality studies.

Subject strategy as opposed to experimental stimulus attributes has also been implicated in observed laterality effects in studies using the EEG as a dependent measure (Ornstein, Johnstone, Herron, & Swencionis (1980). EEG was monitored during the completion of tests of mental rotation, face recognition, picture completion, arc-circle and circle-circle matching, and part-whole assembly, as well as a verbal test requiring definitions of words. Relative EEG alpha power was indicative of greater right hemisphere involvement during completion of the spatial tasks compared to verbal tasks. Such a result implies differential hemisphere involvement, however it is not clear that the task or the physical characteristics of the stimuli were the cause of the

effect because the mental rotation task showed a pattern like the verbal task. Such a result suggests greater left hemisphere involvement in a purported right hemisphere process employing spatial stimuli and a spatial task. Ornstein et al. (1980) concluded that an individual subject's strategy might be the critical factor (instead of the task) determining the relative magnitude of hemisphere involvement. That is, they suggested that the mental rotation task was sufficiently complex to encourage an analytic, verbal strategy. In our opinion these strategies are regulated by the metacontrol system.

What About Differential Brain Organization?

Not only do most people use their brains in an integrative fashion during cognitive processing, they seem to differ, qualitatively and quantitatively, in regard to the functional neural substrates they use to perform complex tasks. There is, in fact, an accumulating body of evidence indicating that people vary in brain organization and that this differential organization is related to differences in cognitive style (Dunn, 1983, 1985b; Languis & Kraft, 1985; Levy, 1980; Reddix & Dunn, 1984). For example, there appear to be gender differences in the relative maturation rate of the left and right hemispheres and the inter- and intra-hemispheric brain organization in adult men and women. These biological differences, in turn, have been related to differential cognitive performance between the sexes (see Levy, 1980; McGlone, 1980, for reviews). Further, other biological traits like handedness, eyedness, and hand posture during writing have also been correlated with differences in cerebral asymmetry and cognition (Kraft, 1982a, 1982b; Levy & Reid, 1976, 1978; Merrel, 1957). Because the literature is fairly clear

concerning the relation of gender to cerebral organization and cognition, we will briefly review some of the more robust findings, particularly since it relates to our own research.

Sex differences. Several researchers have found that the right hemisphere of boys matures earlier than the right hemisphere of girls especially in terms of processing visuospatial material (e.g., Reid, 1980; Witelson, 1976). Others have found more pronounced left-hemisphere maturation in girls, who in contrast to boys, show a perceptual superiority for verbal material (Bryden, 1970; Kimura, 1967; Reid, 1980).

The literature, however, does not allow us to reach the simple conclusion that females are relatively superior to males in left-hemispheric functioning and that males are superior at those functions attributed to the right hemisphere. It depends on exactly which right- and left-processes are being considered. Levy (1980), argues in her review that rather than large right-left differences, males and females differ more in how their respective hemispheres are organized.

Specifically, she argues that the within-hemisphere organization of the two sexes is quite different, with females being superior on several left-hemisphere functions like verbal fluency, rote verbal memory, and forming flexible verbal associations among conceptually distant ideas. Males, on the other hand, appear to be superior at using logical relations and analytical reasoning. In terms of right-hemisphere attributes, females have a better memory for unstructured and incidental input; have greater perceptual speed; and can integrate contextual situations better than males. In contrast, males are better at extracting formal spatial relationships and being more field

independent. Thus, the literature suggests that it is the type rather than the amount of specialized hemispheric functions that exists between the sexes.

Taken together, the neurocognitive research indicates: 1) that the whole brain is used during complex tasks, 2) the brain's hypothesized metacontrol or executive system may use different strategies to differentially engage the cerebral hemispheres to perform certain tasks (as suggested by the literature on hemispheric switching when the same stimuli are processed under different instructions), and 3) people may vary in the way their brain is organized, and that these "unequal patterns" of organization, account, in part. for cognitive style differences (Dunn, 1985a, 1985b; Kraft, 1981, 1983, 1985; Languis & Naour, 1985; Levy, 1980).

Our research has been related to all three of these propositions, particularly the latter concerning brain organization and cognitive style. In our laboratory, like Dr. Languis's Brain/Behavior Laboratory at Ohio State, we rely more on EEG measurements than on handedness, eyedness, dichotic listening, visual-half field, and other indexes of laterality and cognitive style (Dunn et al., 1981; (Hymes, Dunn, Gould, & Harris, 1977; Reddix & Dunn, 1984; Rust, 1982).

Most of our early research was based on bimodal theory. According to bimodal theory, the human brain has a least two qualitatively different modes of thought: the analytic mode which is a logical, linear, and sequential processing system and the holistic mode which is a simultaneous, parallel, or gestalt processing system. Note, again, that these modes are not a function of simple left vs. right hemisphere dependency (see above). They are, in our view, caused by dynamic interactions of various brain systems.

Several researchers (Deikman, 1976; Dunn, 1985a; Hymes et al., 1977) point out that although every person utilizes these two modes, some people typically use one more than the other. Thus, it is possible for one person to be predominantly analytical in processing style and another to be more holistic. An extreme analytic would be one who would prefer a logical, methodological approach to problem solving and text comprehension. An extreme holistic, in contrast, would be one who relies more on intuition than logic in performing these tasks. Hence, an analytical person would tend to process text in a logical (or hierarchical), sequential manner; whereas, a holistic would tend to use more paralogical or gestalt processing. Deikman (1971, 1976) argues that the two modes can be determined by EEG patterns. Specifically, he hypothesized that when people are in the holistic mode, they tend to be relaxed and produce an abundance of alpha (8-13 Hz) activity and that when they are in the analytic state, they are more alert and produce less alpha activity.

All of our previous research has supported these notions. When analytics are given either word-lists or expository text, each having an <u>inherent</u> logical structure, they tend to produce recall protocols reflecting that inherent structure, whereas holistics do not. Holistics appear to use paralogical strategies to recall the material. For example they do not cluster or organize word-lists at recall and, as a group, they recall more descriptive, detail oriented, and logically subordinate information from tightly organized exposition than do analytics.

You will note, that up to this point, only one extreme of the modal cognitive style continuum had been tested by us. That is, all subjects in

both our word-list and expository text experiments were given material with either an implicit or explicit logical organization. This favored analytic processors who, according to theory, should excel at learning this type of material. We argue that if bimodal theory is correct, then extreme holistics should recall relatively more information from text that reflects their intuitive or gestalt-like processing style. The type of text we chose as stimulus material when investigating this issue in subsequent experiments, (Reddix, 1983; Reddix & Dunn, 1984) and a rational for its use, is presented below.

Methods and Procedures

Participants read two poetry selections. It will be important to briefly delineate the criteria which differentiate some poems as being more holistic in nature relative to others. Independent raters selected two poems for use as stimulus materials. The poems were judged to lie at opposite ends of a continuum of holistic attributes. Poetry was considered as highly holistic stimulus material if it was rated high on the following: a) high use of metaphor and imagery, b) the use of metaphor and imagery that are central to the theme and denouement of the poem, c) high in emotional appeal, d) greater use of concrete words relative to abstract words, and e) a low level of logical structure. Less holistic poetry had the opposite attributes: a) argument central to the theme; metaphor and imagery secondary, b) relatively less emotional appeal, c) greater use of abstract words as compared to concrete words and/or less use of noun modifiers (adjectives), and d) an obvious logical structure or a relatively greater logical structure. The highly holistic poetry selection (see Table 1), "Seals, Terns, Time"

(Eberhart, cited in Brown & Milstead, 1968), will be referred to as descriptive poetry. The less holistic poetry selection (see Table 2), "The Horse Chestnut Tree" (Eberhart, cited in Brown & Milstead, 1968), will be referred to as argumentative poetry. Neither poetry selection contained rhyme sequences. Experimental poetry passages were reproduced on 35mm slides (one stanza/slide). Right handed male and female college student participants controlled there own stanza presentation rate. Prior to the reading of each experimental poem participants were told that they would be expected to recall as much of the poem as possible (in any order they wished) immediately after reading of the last stanza.

Insert Table 1 and 2 about here

Electrophysiological recordings were made during the reading of each stanza from two parietal temporal sites; i.e., from a point midway between P_3 and T_3 on the left hemisphere, and midway between P_4 and T_4 on the right, in accordance with the 10-20 Electrode System (Jasper, 1958). This allowed for observations of differential hemisphere activation. Recording sites were referenced to C_z yielding two bipolar recordings. A linked-ears reference was also used, allowing for the comparison of bipolar and monopolar recording techniques, the differences between which are not important here. Following our past research (Dunn et al, 1981; Hymes et al., 1977) subjects were dichotomized into analytic and holistic processors based on their average bilateral alpha activity produced during a five minute eyes open baseline period. Subjects average alpha was rank ordered and those whose alpha was

below the median were designated as analytics. Those whose alpha scores were above the median were categorized as holistics.

Proportional metaphor recall protocols were analyzed separately using a four-way mixed analysis of variance. The independent variables were cognitive style, gender, poem, and level (level of metaphoric relationship in the content structure of the poem). Poem and level were repeated measures. Data analyses utilized arcsine transformation, however, the reader should note that non-transformed data yielded equivalent significant results.

Of greatest importance is the significant three-way interaction of poem by cognitive style by gender which is shown in Figure 1 as two 2-way components for ease of discussion. Notice that males follow the predictions of bimodal theory with male holistics recalling more from the descriptive, most holistic poem, compared to male analytics. Also note the differential recall pattern of males and females which suggests a possible gender difference in modal processing.

Insert Figure 1 about here

Our alpha data, collected on line during the reading of the poetry (especially the relative alpha data at both C_z and linked ears) also support possible gender differences. With both sets of data, a significant three-way, gender by hemisphere by reading slide, and a significant four-way, cognitive style by gender by poem by slide interaction was obtained. The data were at best messy and at worst uninterpretable! Consequently, for descriptive purposes only, Figures 2 and 3 show these data collapsed across slide, reducing them to two-

and three-way interactions respectively.

Three interesting observations emerge from these data. First, it appears that males were primarily responsible for the hemispheric differences in alpha (see Figure 2). Secondly, holistics produced more mean alpha than did analytics, thus supporting our previous work using expository text (e.g., Dunn et al., 1981). Finally, it is interesting to note that differential gender effects may occur within a processing style (see Figure 3). We observed that: 1) female analytics produced slightly greater amounts of mean alpha than male analytics, 2) male holistics produced slightly greater amounts of alpha than female holistics, and 3) in contrast to our previous work (Dunn et al., 1981) which showed that all subjects (both analytic and holistic) produced more alpha in their left hemispheres during the reading of expository text, the present data using poetry, indicate that most subjects produced more alpha in their right hemisphere.

Insert Figure 2 and 3 about here

This suggests that while reading <u>exposition</u> the right hemisphere is relatively more engaged than the left hemisphere (similar findings have been obtained by Kraft, Mitchell, Languis, & Wheatly, 1980). The opposite occurs when subjects read abstract poetry. In any case, different text appears to require differential cerebral activation.

What are we to make of this interaction of gender and style with "holistic text." Given the correlative brain activity data we have reported, there is prima-facie evidence for "real" gender differences in cognitive

processing. As you will recall the work by Sandra McGlone (1980) and Jere Levy (1980), reported earlier, suggests these apparent gender differences may be due, in part, to differences in the within-hemisphere organization of the two sexes. Although an interesting topic for future research, the point we would like to stress (as we have several times before e.g., Dunn, 1985b) is that differential brain organization may lead to differences--possibly qualitative differences—in cognitive style. If so, a universal instructional approach applied to all students may not be appropriate.

Although we have been able to reliably identify two extreme cognitive styles using EEG alpha measurements (i.e., analytic and holistic), we do not want to leave the impression that we believe analytics and holistics are extreme styles on a single continuum. They should not be viewed as a dichotomy. Figure 4 shows that we believe any person's cognitive style is based, in part, on different mixtures of analytic and holistic thought.

Insert Figure 4 about here

Consequently, a high analytic is someone who has an excess of analytical skills relative to their holistic ability. We are very aware, as also can be seen from Figure 4, that some people are well versed at both types of processing (in the experiment just presented female analytics would fall into this category) whereas others are not. Most of us probably cluster somewhere around the middle of the figure.

Based on these assumptions, our future research will be focused on identifying people in the outlying areas of the four quadrants whose mixture

is unique enough to be considered a separate cognitive style. A promising method for use in future investigations of this issue is topographic mapping of the brain while subjects are engaged in various cognitive tasks. Topographic mapping will be discussed later in this symposium by Mike Torello.

Discussion

As can be seen in Figure 5 a pattern appears to be emerging if all of our data across all our experiments is examined as a whole.

Insert Figure 5 about here

When expository text is structured using tight cause and effect relations (Breeder Reactor passage, Dunn et al., 1981) both male and female analytics recall more superordinate or gist information than either male or female holistics. The center of this figure indicates that as exposition loses logical structure (Sea Floor passage, Dunn et al., 1981) or poetry takes on an argumentative, chronological structure (Reddix, 1983; Reddix & Dunn, 1984) then no differences in recall across gender or cognitive style are obtained. However, as prose shifts to a highly abstract or holistic vein (descriptive poetry, Reddix, 1983; Reddix & Dunn, 1984) a gender by style interaction occurs. Males again follow the pattern predicted by bimodal theory, i.e., male holistics recall the gist, male analytics to not. Thus, for males, bimodal theory predicts their recall pattern for both types of text quite well. In contrast, both female analytics and holistics recall the gist of the "holistic" poem. Thus for female analytics bimodal theory predicts recall only when text is highly organized and in expository form.

We would like to stress that these points are highly speculative since they are based on separate studies, each of which used different scoring systems, and different subjects. We are, however, currently running a within subjects experiment using expository text and poetry in order to test these notions.

Implications for Education

Theoretically, the best education would come from truly individualized instruction as was proposed by John Dewey and others many years ago. However, given the pragmatics of the American school system (e.g., large classrooms and limited resources), we probably will only be able to develop individualized curriculum to meet the needs of groups of students having differing cognitive styles or abilities. We remain skeptical, however, of uncritically adopting a simple left-right or "hemisphericity" theory of brain functioning as a basis for educational practice given the accretion of neurophysiological and psychological research which suggests that as the complexity of the information we are asked to process increases, the whole brain is used, regardless of the type of information (verbal or pictorial) to be processed. What we are proposing is that curricula be developed to meet the needs of a least the major types of cognitive styles which have been, and will be, identified by researchers in the next several years.

If, as we have implied earlier, some of these individual differences are biologically based, then research will have to be conducted to determine if these biological differences are modifiable. We argue that the use of ongoing EEG may provide a useful yardstick for monitoring an individuals ability to appropriately, or inappropriately, shift (modify) modal processing style to

meet current task demands.

It is obvious that the whole idea of biologically determined processing styles brings up several ethical issues. For example, should we actively attempt to change a person's style, should we adapt curricula to compliment that style, or should we do both? We believe that every student should be taught that in most cases there are several strategies that can be used (separately or in combination) to solve any problems in any content domain (including mathematics). Consequently, since we also think that the brain's metacontrol system is most adaptive when it has numerous strategies at its disposal, like analytic and holistic strategies, teaching strategic knowledge and cognitive flexibility should be stressed to all students in our schools (Until we investigate, more throughly, the cognitive attributes of each style, this will be hard to do.) In fact the notion of "cognitive flexibility" and its educational implications is currently being investigated by Rand Spiro and his colleagues [see Spiro. Vispol, Schmit, Samarapungavan, and Boerger (in press)] at the Center for the Study of Reading, University of Illinois @ Urbana-Champaign.

References

Andersen, P., & Andersson, S. A. (1968). Physiological basis of the alpha rhythm. New York: Appleton.

Basso, A., Bisiach, E., & Capitoni, E. (1977). Decision in ambiguity: Hemispheric dominance or interaction? Cortex, 13. 96-99.

Brown, H., & Milstead, J. (1968). Patterns in poetry: An introductory anthology. Glenview, IL: Scott, Foresman.

Bryden, M. P. (1970). Laterality effects in dichotic listening: Relations with handedness and reading ability in children. Neuropsychologia. 8, 443-450.

Cohen, G. (1972). Hemispheric differences in a letter classification task. Perception and Psychophysics, 11, 139-142.

Cohen, G. (1975). Hemisphere differences in the effects of cuing in visual recognition tasks. Journal of Experimental Psychology: Human Perception and Performance, 1, 366-373.

Das, J. P., Kirby, J., & Jarman, R. F. (1975). Simultaneous and successive synthesis: An alternative model for cognitive abilities. Psychological Bulletin, 82, 87-103.

Deikman, A. J. (1971). Bimodal consciousness. Archives of General Psychiatry. 25. 481-489.

Deikman, A. J. (1976). Bimodal consciousness and the mystic experience. In P. R. Lee, R. E. Ornstein, D. Galin, A. J. Deikman, & C. T. Tart (Eds.), Symposium on consciousness. New York: The Viking Press.

Dunn. B. R. (1983). Electrophysiological and prose recall determinants of cognitive style: New directions for prose research. In B. R. Dunn (Chair),

Prose research and analysis: A 10 year retrospective. Symposium conducted at the annual meeting of the American Psychological Association, Anaheim, California.

Dunn, B. R. (1985a). Bimodal processing and memory from text. In V. M. Rentel, S. Corson, & B. R. Dunn (Eds.). Psychophysiological aspects of reading and learning. New York: Gordon & Breach Science Publishers.

Dunn. B. R. (1985b, March). Brain organization and cognitive style: Facts, Fancies, and possibilities. Invited paper presented at the 11th Western Symposium on Learning, Cognition, and Instruction. Western Washington University.

Dunn, B. R., Gould, J. E., & Singer, M. (1981). Cognitive style differences in expository prose recall (Tech. Rep. No. 210). Urbana-Champaign: University of Illinois, Center for the Study of Reading.

Edwards. B. (1979). Drawing on the right side of the brain. New York: St. Martin's Press.

Freides, D. (1977). Do dichotic listening procedures measure lateralization of information processing or retrieval strategy? Perception and Psychophysics, 21, 259-263.

Galin, D. (1974). Implications for psychiatry of left and right cerebral specialization. Archives of General Psychiatry, 31. 572-583.

Gerfen, G., Bradshaw, J. L., & Nettleton, N. C. (1972). Hemispheric asymmetry: Verbal and spatial coding of visual stimuli. Journal of Experimental Psychology, 95, 25-31.

Goldberg, E., & Costa. L. D. (1981). Hemisphere differences in the acquisition and use of descriptive systems. Brain and Language, 14, 144-

173.

Hardyck, C., Tzeng, O. J. L., & Wang, W. (1978). Cerebral lateralization of functions and bilingual decision processes: Is thinking lateralized? Brain and Language, 5, 56-71.

Heeschen, C., & Jurgens, R. (1977). Pragmatic-semantic and syntactic factors influencing ear differences in dichotic listening. Cortex, 13, 74-84.

Hymes, D., Dunn, B. R., Gould, J. E., & Harris, W. (1977). Effects of mode of conscious processing on recall and clustering. Paper presented at the meeting of the Southeastern Psychological Association, Hollywood, Florida.

Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. Cortex, 3, 163-178.

Kraft, R. H. (1981). The relationship between right-handed children's assessed and familial handedness and lateral specialization. Neuropsychologia, 19, 697-705.

Kraft, R. H. (1982a). Relationship of ear specialization to the degree of task difficulty, sex, and lateral specialization. Perceptual and Motor Skills, 54, 703-714.

Kraft, R. H. (1982b). Hemispheric specialization and integration and its relationship to stages of language and cognitive development. Paper presented at the 5th International Conference in Child Neurology, Bratslava, Czechoslavakia.

Kraft, R. H. (1983). The effect of sex, laterality and familial handedness on intellectual abilities. Neuropsychologia. 21, 79-89.

Kraft, R. H. (1985). Asymmetric brain specialization: Proposed relationship between its development and cognitive development. In V. Rentel, S.

Corson, & B. R. Dunn (Eds.), Psychophysiological aspects of reading and learning. New York: Gordon & Breach Science Publishers.

Kraft, R. H., Mitchell, R. O., Languis, M. L., & Wheatly, G. H. (1980). Hemispheric asymmetries during six-to-eight year olds performance of Piagetian conservation and reading tasks. Neuropsychologia, 18, 637-643.

Languis, M. L., & Kraft, R. H. (1985). The neuroscience and educational practice: Asking better questions. In V. Rentel, S. Corson, & B. R. Dunn (Eds.), Psychophysiological aspects of reading and learning. New York: Gordon & Breach Science Publishers.

Languis, M. L., & Naour, P. L. (1985). Sex differences in neuropsychological functions: A reactor model. In C. L. Hartlage, & C. F. Telgrow (Eds.). The neuropsychology of individual differences: A developmental perspective. New York: Plenum.

Levy, J. (1980). Cerebral asymmetry and the psychology of man. In M. Wittrock (Ed.), The brain and psychology. New York: Academic Press.

Levy, J., & Reid, M. (1976). Variations in writing posture and cerebral organization. Science, 194, 337-339.

Levy, J., & Reid, M. (1978). Variations in cerebral organization as a function of handedness, hand posture in writing, and sex. Journal of Experimental Psychology: General, 107, 119-144.

Levy-Agresti. J., & Sperry, R. W. (1968). Differential perceptual capacities in major and minor hemispheres. Proceedings of the National Academy of Sciences. U.S.A., 61, 1151.

Levy, J., & Trevarthen, C. (1976). Metacontrol of hemispheric function in human split-brain patients. Journal of Experimental Psychology: Human

Perception and Performance, 2, 299-312.

Luria, A. R. (1973). The working brain: An introduction to neuropsychology (B. Haigh, Trans.). New York: Basic Books, Inc.

McGlone. J. (1980). Sex differences in human brain asymmetry: A critical survey. Behavioral and Brain Sciences, 3, 215-263.

Merrel, D. J. (1957). Dominance of hand and eye. Human Biology, 23, 314-328.

Reddix, M. D. (1983). EEG alpha production correlates of cognitive style differences and recall from poetry. Unpublished master's thesis, University of West Florida, Pensacola, FL.

Reddix, M. D., & Dunn, B. R. (1984). EEG alpha production correlates of cognitive style differences and recall of metaphor from poetry. Urbana-Champaign: University of Illinois, Center for the study of reading.

Reid, M. (1980). Cerebral lateralization in children: An ontogenetic and organismic analysis. Unpublished doctoral dissertation, University of Colorado, CO.

Rust, D. T. (1982). EEG alpha responses related to semantic recall in two groups of children. Unpublished doctoral dissertation. Walden University, FL.

Searleman, A. (1977). A review of right hemisphere linguistic capabilities. Psychological Bulletin, 84, 1-14.

Segalowitz, S. J., & Stewart, C. (1979). Left and right lateralization for letter matching: Strategy and sex differences. Neuropsychologia. 17. 521-525.

Sergent, J. (1982a). About face: Left-hemisphere involvement in processing physiognomies. Human Perception and Performance. 8. 253-272.

Sergent, J. (1982b). The cerebral balance of power: Confrontation or cooperation? Journal of Experimental Psychology: Human Perception and Performance, 8, 253-272.

Sergent, J., & Bindra, D. (1981). Differential hemispheric processing of faces: Methodological considerations and reinterpretation. Psychological Bulletin, 89, 541-554.

Shucard, J. L., Shucard, D. W., Cummins, K. R., & Campos, J. S. (1981). Auditory evoked potentials and sex-related differences in brain development. Brain and Language, 13, 91-102.

Shucard, D. W., Shucard. J. L., & Thomas, D. G. (1977). Auditory evoked potentials as probes of hemispheric differences in cognitive processing. Science, 197, 1295-1298.

Spellacy, F, & Blumstein, S. (1970). The influence of language set on ear preference in phoneme recognition. Cortex. 6. 430-439.

Spiro, R. J., & Myers, A. (1984). Individual differences and underlying cognitive processes in reading. In P. D. Pearson (Ed.), Handbook of reading research. New York: Longman Inc.

Spiro, R. J., Vispoel. W., Schmitz. J.m Samarapungavan, A., & Boeger, A. (in press). Mental representations in complex content domains: Knowledge acquisition for adaptive flexibility and transfer. In B. Britton (Ed.), Executive Control Processes. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

White, M. J., & White, K. G. (1975). Parallel serial processing and hemispheric function. Neuropshchologia. 13, 377-381.

Witelson, S. F. (1976). Sex and the single hemisphere: Right hemisphere

specialization for spatial processing. Science, 193. 425-427.

Zaidel, E. (1976). Auditory vocabulary of the right hemisphere following brain bisection or hemidecortication. Cortex, 12, 191-211.

Zaidel, E. (1977). Unilateral auditory language comprehension on the Token Test following cerebral commissurotomy and hemispherectomy. Neuropsychologia, 15, 1-18.

Zutell, J. (1985). Linguistic and psycholinguistic perspectives on brain mechanisms and language. In V. Rentel, S. Corson, & B. R. Dunn (Eds.), Psychophsiological aspects of reading and learning. New York: Gordon & Breach Science Publishers.

Table 1

Seals, Terns, Time

Structure	Stanza
	The seals at play off Western Isle
micro	In the loose flowing of the summer tide
	And burden of our strange estate-
	Resting on the car and lolling on the sea,
micro	I saw their curious images,
	Hypnotic, sympathetic eyes
	As the deep elapses of the soul.
micro	O ancient blood, O blurred kind forms
	That rise and peer from elemental water:
	I loil upon the car, I think upon the day,
micro	Drawn by strong, by the animal soft bonds
	Back to a dim pre-history;
	While off the point of Jagged Light
micro	In hundreds, gracefully, the fork-tailed terns
	Draw swift esprit across the sky.
	Their aspirations dip in mine,
micro	The quick order of their changing spirit,
	More freedom than the eye can see.
	Resting lightly on the oarlocks,
macro	Pondering, and balanced on the sea,
	A gauze and spindrift of the world,
	I am in compulsion hid and thwarted,
macro	Pulled back in the mammal water,
	Enticed to the release of the sky.

Note. Author: Richard Eberhart (cited in Brown & Milstead, 1968, p. 132).

Table 2

The Horse Chestnut Tree

Structure	Stanza
micro	Boys in sporadic but tenacious droves Come with sticks, as certainly as Autumn, To assault the great horse chestnut tree.
micro	There is a law governs their lawlessness. Desire is in them for a shining amulet And the best are those that are highest up.
micro	They will not pick them easily from the ground. With shrill arms they fling to the higher branches, To hurry the work of nature for their pleasure.
micro	I have seen them trooping down the street Their pockets stuffed with chestnuts shucked, unshucked. It is only evening keeps them from their wish.
micro	Sometimes I run out in a kind of rage To chase the boys away; I catch an arm, Maybe, and laugh to think of being the lawgiver.
micro	I was once such a young sprout myself And fingered in my pocket the prize and trophy. But still I moralize upon the day
macro	And see that we, outlaws on God's property, Fling out imagination beyond the skies, Wishing a tangible good from the unknown.
macro	And likewise death will drive us from the scene With the great flowering world unbroken yet, Which we held in idea, a little handfull.

Note. Author: Richard Eberhart (cited in Brown & Milstead, 1968, p. 132).

Figure Captions

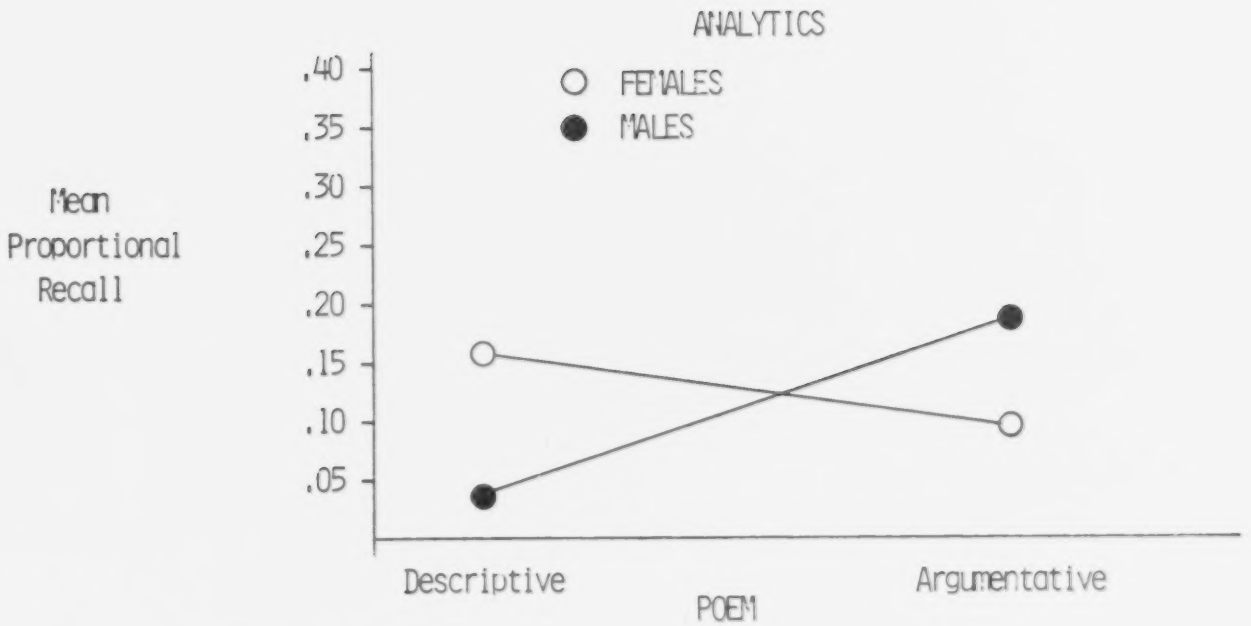
Figure 1. Mean proportional metaphor recall as a function of poem, cognitive style, and gender.

Figure 2. Mean relative alpha production as a function of gender and hemisphere.

Figure 3. Mean relative alpha production as a function of cognitive style, gender, and poem.

Figure 4. A multidimentional representation of cognitive style.

Figure 5. The effect of prose structure on the recall of individuals who differ in cognitive style.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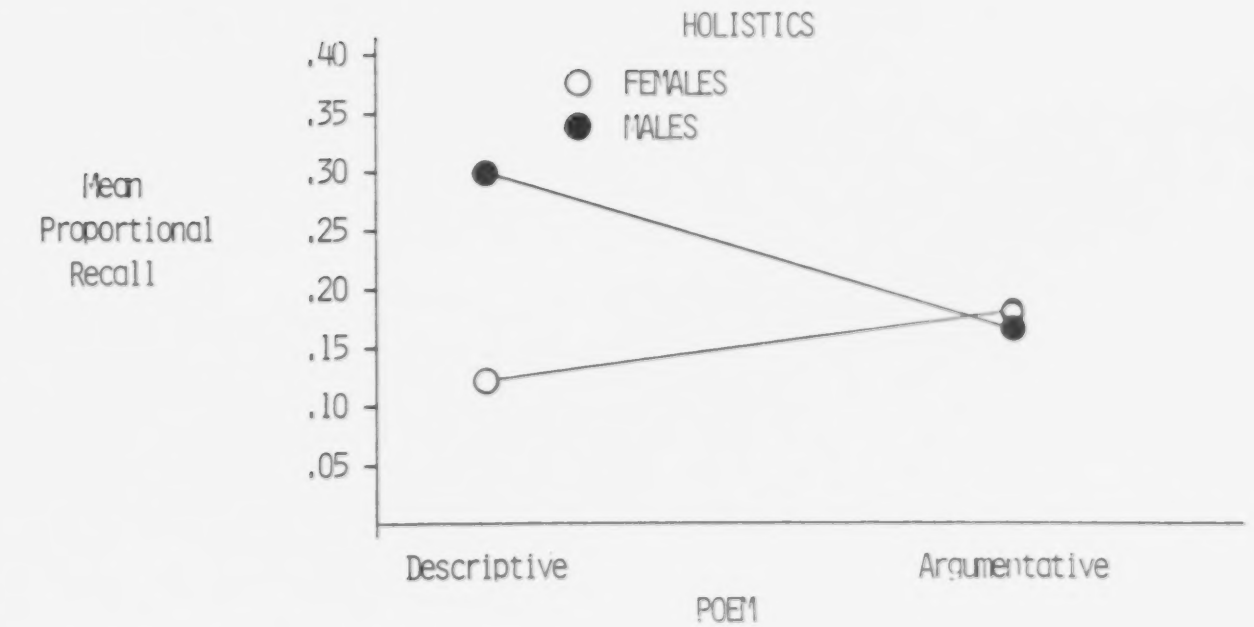
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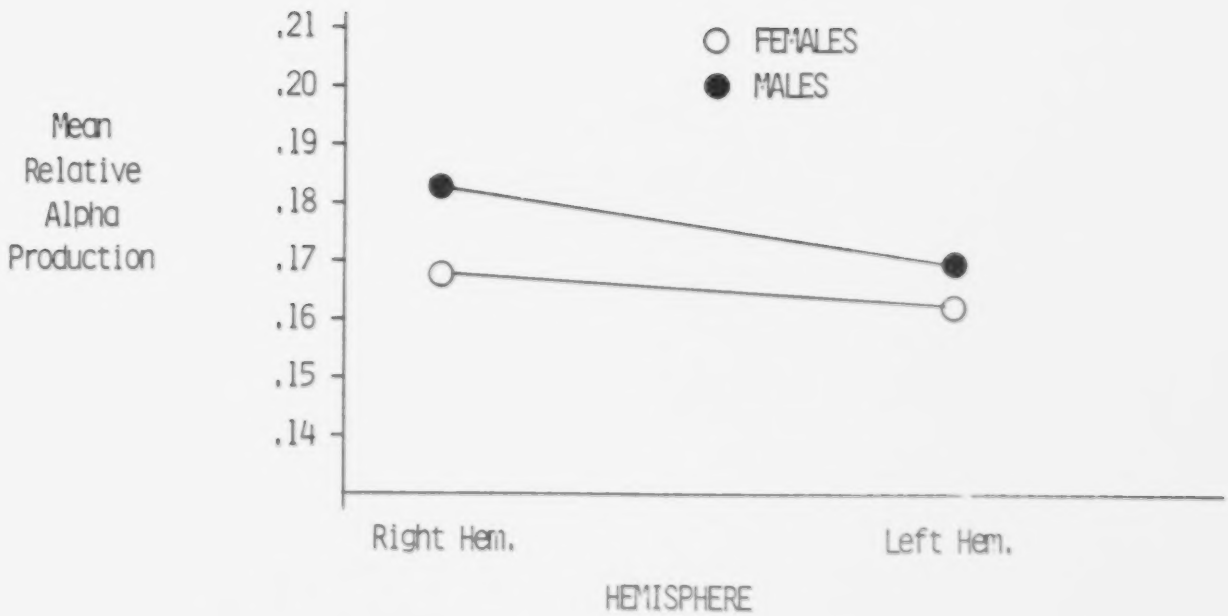
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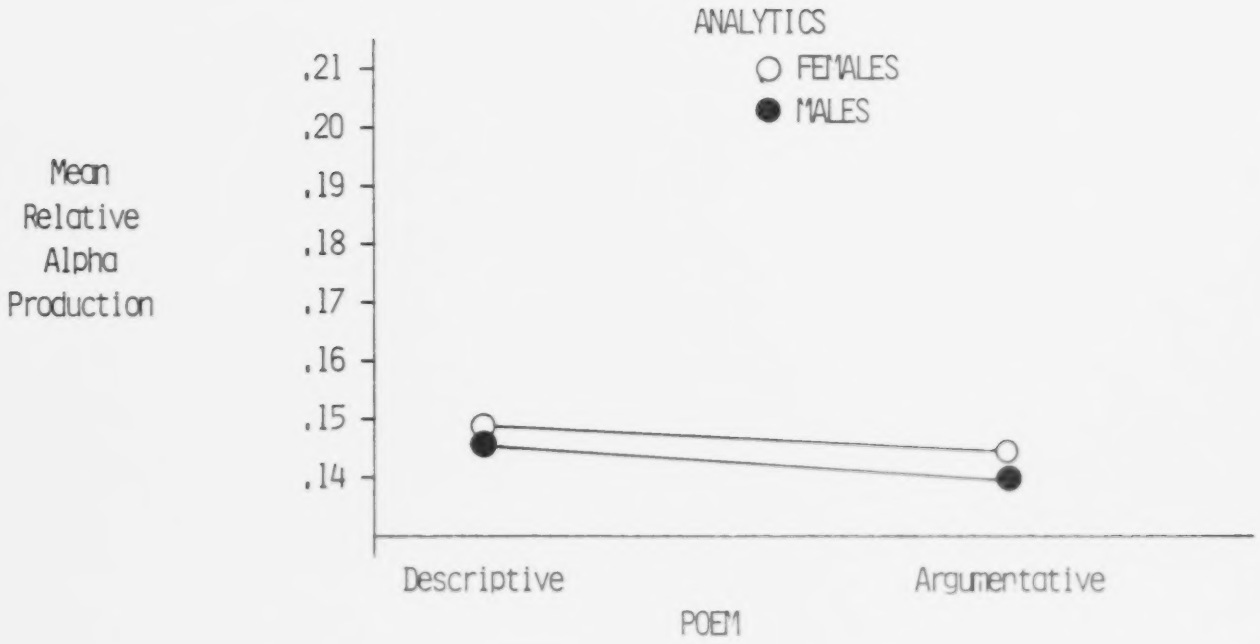
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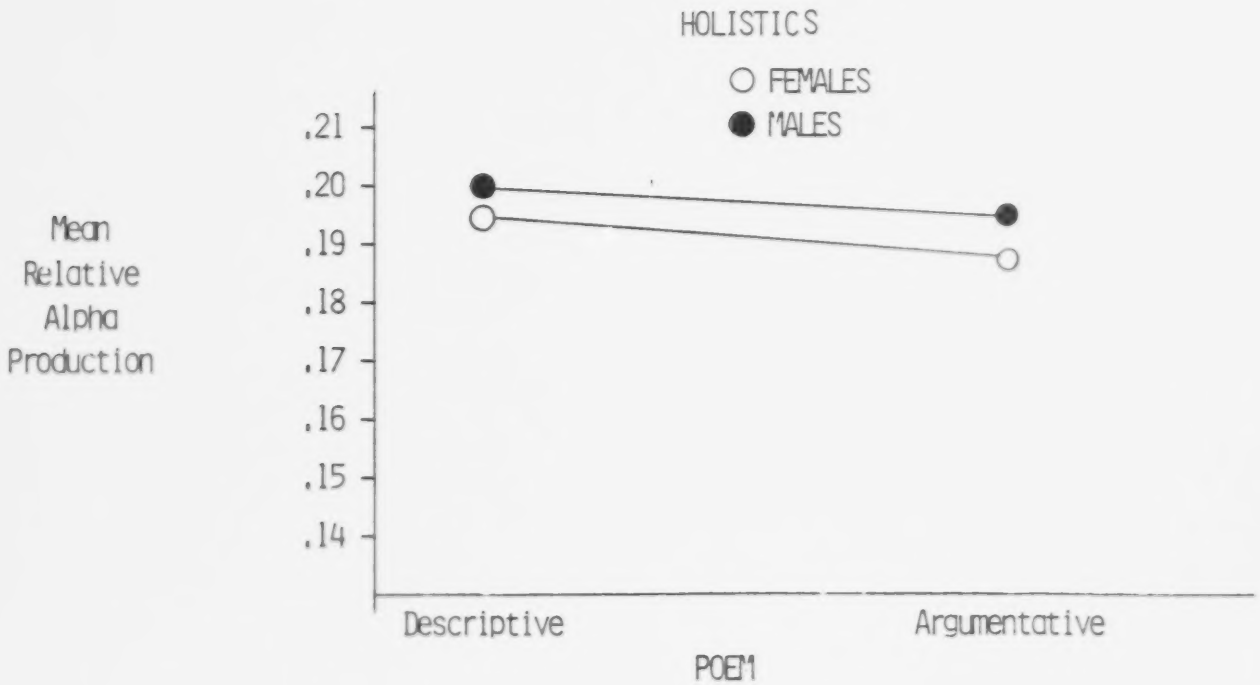
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Analytical
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+(An Einstein)
+(Anally
Constrained
Bore)
Holistic
(High)
Holistic
(Low)
+(Space Cadet)
Analytical
(Low Usage)
+(Mentally Disabled)

Dunn, Gould, & Singer (1981)
(Expository Text Study)

Reddix & Dunn (1984)
(Poetry Study)